U.S. Department of Transportation

**Federal Aviation Administration**

# Memorandum

Subject: **ACTION**: Review and Concurrence, Equivalent Level of Safety Finding for Cessna's AMETEK AMLCD Engine Indicator project on a Cessna Model 550 Bravo

Date: November 01, 2002

FAA Project Number TD2216WI-T

From: Manager, Propulsion/Mechanical Systems Branch, ANM-112

Reply to Attn. of: Bob Adamson, ACE-118W, 316-946-4145

To: Tina L. Miller, FAA Program Manager, ACE-117W

ELOS Memo#: TD2216WI-T-P-1

**Background**

Cessna Aircraft Company has requested an Equivalent Level of Safety to 14 CFR part 25.1549(a) through (d) as required by 14 CFR part 21.21(b)(1). Cessna utilizes electronic displays of engine instruments and proposes to display engine high pressure turbine speed ($N_{2)}$ and engine fuel flow indication by digital display. Both indicators are incorporated into an Active Matrix Liquid Crystal Display (AMLCD). This request pertains to the use of a digital display for engine $N_2$ and fuel flow on the Cessna Model 550 (Bravo).

The Model 550 (Bravo) uses electronic displays for those powerplant instruments required by 25.1305 (c)(2) and (3). Both the high pressure turbine rotor speed ($N_2$), and fuel flow are an all digital numeric presentation.

The primary engine displays on turbine engine powered transport aircraft have traditionally displayed the required engine rotor speeds, oil temperature, oil pressure and fuel flow required by §25.1305 in an analog-only or an analog and digital format. Standby Engine Indicators (SEI's), when provided, have typically displayed these parameters in either analog-only or digital-only format. An increasing demand to conserve primary display space has led to digital-only primary displays for various engine parameters including those rotor speeds not used for power setting. This situation may result in a small, cluttered, low-resolution primary display.

In addition, it is generally accepted that digital-only displays are often less effective than conventional analog displays at providing the crew with discernible indication of the parameter during a rapid transient, and quick intuitive indication of the parameters approximate level, direction and rate of change, proximity to limits, and relationship to other parameters on the same engine or the same parameter on other engines. This is why AC 20-88A, paragraph 4(c), states that "digital indicators are most valuable when integrated with an analog display."

While an analog format is not required to comply with most of the referenced rules, §25.1549 requires instrument markings, which presume an analog type display, format. Consequently, features of the digital format must at least provide a level of safety equivalent to that intended by compliance with §25.1549.

Other avionics installations in similar Cessna airplanes have been granted an Equivalent Level of Safety for direct reading, digital only displays for $N_2$. A partial list of these applications include Cessna Models 550, S550, 552 and 560 airplanes on Type Certificate Data Sheet (TCDS) A22CE, and the Cessna Model 750 on TCDS T00007WI.

This memo contains information concerning the Cessna Model 550 (Bravo) electronic display, which are above and beyond the goal of seeking an Equivalent Level of Safety to §25.1549. It is left intact for the reader's information and understanding of methodology used by Cessna to show compliance for this electronic display.

**Applicable regulations**
§§ 21.21(b)(1), 25.901(c), 25.1309(a), (b) and (c), 25.1321(c), 25.1549

**Regulation requiring an ELOS**
§§ 25.1549 (a) through (d)

**Description of compensating design features or alternative standards which allow the granting of the ELOS (include design changes, limitations or equipment need for equivalency) and Explanation of how design features or alternative standards provide an equivalent level of safety to the level of safety intended by the regulation**

**Digital Only Turbine Speed (N2) Indicator**
Cessna has requested the current Equivalent Level of Safety finding for the Citation Bravo digital only $N_2$ indication on the mechanical engine instruments be extended to the AMLCD installation based on the following justification.

For all normal operating conditions, the primary power setting on the PW530A engine installation on the Model 550 Bravo is $N_1$ (fan speed). The high pressure turbine speed ($N_2$) is used for engine starting and overspeed monitoring. During engine starting, the throttles are advanced when the N2 speed increases above 8%, which is easily readable on the digital display. During the rest of the start sequence, the $N_2$ display is used only to verify engine acceleration up to idle speed. The display responds proportionally to the rate of change of speed during any acceleration, so the flight crew can verify proper acceleration. During any overspeed condition of the high pressure rotor, the $N_2$ display changes color from green to red which is also easily recognized on the digital display. As noted earlier, this change in display color has been found to meet the intent of and provide an equivalent level of safety to §25.1549. This is similar to the existing, previously certified aircraft, which incorporates only a flashing red overspeed warning light when the redline limit is exceeded, with no other indication or placard defining the rotor speed limits.

The PW530A engine is controlled by a hydromechanical fuel control. Cessna has, in the past, used a digital only display for this parameter on similar hydromechanically controlled engine

installations. All Citation 525, 550 and 560 series aircraft, including the original configuration Model 550 Bravo have similar limitations and are certified with a digital only $N_2$ speed display. The PW530A fuel control unit provides a built in overspeed protection which limits the maximum $N_2$ speed to 100.6%. In the event of an FCU governor failure, the $N_2$ could exceed this limit. If this maximum $N_2$ speed is exceeded, the HP turbine blades are designed to erode due to the resulting high temperature and dynamic loads before the engine would reach a speed where the rotor could burst.

§25.1549(a) requires each maximum and, if applicable minimum, operating limit be marked with a red line or red radial. The maximum limit for $N_2$ as established by the PW530A Installation Manual is 100%. The PW530A Installation Manual does not define any minimum N2 operating limits. The AMLCD system $N_2$ speed display provides a digital readout from 0 to 115% with a resolution of 0.1%. The digital display changes from green to red when $N_2$ exceeds the redline limit plus the display resolution limit (i.e. the display changes to red at 100.1% $N_2$). The change in color of the display provides an overspeed warning to the pilot. The built in overspeed protection of the FCU precludes the need for an accurate reading of the rate of change of $N_2$, as would be provided by a tape or dial gage marked with a red line or radial. Since the FCU limits the maximum overspeed of the engine to 100.6%, and operation at this speed is allowed per the PW530A Installation Manual for up to 20 seconds before any maintenance action is required, a digital display of the $N_2$ which alerts the crew when the redline speed of 100% is exceeded provides adequate rate of change information for safe operation. Therefore the digital display of the $N_2$ speed provides an equivalent level of safety to the redline or red arc required by §25.1549(a).

§25.1549(b) requires each normal operating range be marked with a green arc or green line. Normal operation of the engine high pressure rotor speed is displayed by illuminated steady green digits on a black background and no other indication. The green digits meet the intent of a green arc or green radial. Thus an equivalent level of safety to §25.1549(b) is shown.

§25.1549(c) requires each takeoff and precautionary range be marked with a yellow arc or line. No precautionary or takeoff speed range is required by the PW530A Installation Manual, or by the installation of the engine in the aircraft. Engine high pressure rotor speed is within the normal operating range, unless the redline limit is exceeded, at which point the display changes to red digits on a black background, as described above.

The PW530A Installation Manual allows an overspeed of up to 2% for up to 20 seconds. This transient limit is also included in the Aircraft Flight Manual table of engine operating limits. Therefore operation at speeds of up to 102% for up to 20 seconds does not create a hazard to the aircraft. In the event of a gradual increase in $N_2$ speed above 100%, the flight crew's action would be the same (i.e. to retard the throttles) whether the display was yellow or red. Therefore a precautionary yellow band would provide no additional level of safety. In the event of a rapid increase in speed, a yellow band would not offer significant additional safety, since the speed would pass through the precautionary range faster than the flight crew could react. In this case, the FCU speed limiting described above would prevent the transient limit from being exceeded. Therefore, the redline notification at 100.1% along with the 20 second transient 102% limitation constitutes equivalency to the precautionary range and is equivalent in safety to the yellow arc required by §25.1549(c).

§25.1549(d) requires each engine speed range that is restricted because of excessive vibration streses must be marked with red arcs or red lines. The Model 550 Bravo engine installation has no high pressure turbine speed restrictions which would require an additional N2 red arc or red marking other than the defined maximum speed limitation of 100%. Therefore an equivalent level of safety is not required for §25.1549(d), as it is not applicable to the Model 550 Bravo.

In summary, the use of an analog display marked in accordance with §25.1549 would not offer additional safety over the $N_2$ digital display contained in the AMLCD system based on the above justification and commonality of engine design and aircraft operation to previously certified Citations. An Equivalent Level of Safety should therefore be extended to the Model 550 Bravo AMLCD installation as defined by ECR40673.

**Digital Only Fuel Flow Indicator**

The Model 550 Bravo will incorporate a fuel flow digital only indicator. The following justification is being provided to show that the Citation Model 550 Bravo engine fuel flow digital only display has an equivalent level of safety and therefore complies with the requirements of FAR 25.1549 (a), (b), (c) & (d).

The Model 550 uses the Pratt and Whitney Canada PW530A engine with a hydromechanical fuel control. Each engine installation incorporates a Cessna installed temperature compensated fuel flow measuring device that provides the signal for the digital fuel flow display. For engine operation, fuel flow may be used as a verification of engine control system operation by providing indication on the initiation of fuel flow to the engine during start (prior to ITT rise), for maintenance, as well as for any requirement for supplemental fuel consumption information. The Pratt and Whitney Canada PW530A Installation Manual does not contain any maximum or minimum operating limits, restricted operating ranges, or specific usage instructions including trend requirements for fuel flow or fuel flow indication. Therefore fuel flow is a parameter where limits, trend, or rate-of-change information may not be considered an important requirement.

The fuel flow digital only numeric indication is displayed on the Active Matrix Liquid Crystal Display (AMLCD) which is centrally located on the instrument panel. The display provides a green digital readout against a black background, with a range from 0 to 1990 PPH and a resolution of 10 PPH. The indication is individually displayed for each engine, and is identified by a white “FUEL FLOW” above the displays. A white “PPH” is located between the display for each engine.

Since no engine operating limit is defined or required, the digits remain green during operation. Response of the digital display system is such that fuel flow information is easily discerned for each engine during both transient and steady state operation. Given the logical display location, engine-to-engine data can be quickly compared. The fuel flow display location has been shown by flight test demonstration to meet the requirements for visibility including appropriate conditions of lighting and panel vibration. With no limit defined by the engine manufacturer or required by the aircraft, no redline or red radials are required, an equivalent level of safety to FAR 25.1549(a) is not required.

The green digits of the display during operation meet the intent of a green arc or green radial, thus an equivalent level of safety to FAR 25.1549 (b) is shown.

As previously stated, no takeoff or precautionary range for fuel flow is required by the PW530A Installation Manual, or by the installation of the engine in the aircraft. Therefore, FAR 25.1549(c) does not apply.

The Model 550 Bravo engine installation has no restricted operating range. Therefore, FAR 25.1549 (d) does not apply.

The digital numeric display is equivalent in safety to the intent of FAR 25.1305 (c)(2) for a fuel flowmeter indicator, is equivalent in safety to the requirements of FAR 25.1549. The use of an analog display would offer no additional safety over the digital fuel flow display based on the above justification, and engine design and aircraft operation. An Equivalent Level of Safety should therefore be extended to the Model 550 Bravo for the digital fuel flow presentation.

**Conclusion**

The FAA concurs with the Cessna Aircraft Company position and finds that an Equivalent Level of Safety to 14 CFR part 25.1549(a) through (d) as required by 14 CFR part 21.21(b) may be granted for the use of direct reading, digital only displays for high-pressure turbine speed ($N_2$), and fuel flow (Wf).

**FAA approval and documentation of the ELOS**

The FAA has approved the aforementioned Equivalent Level of Safety Finding in issue paper P-1. This memorandum provides standardized documentation of the ELOS that is nonproprietary and can be made available to the public. The Transport Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number should be listed in the Type Certificate Data Sheet under the Certification Basis, ELOS section.

*Note – because the contents of this memorandum will be kept as part of the permanent records of the project files, care should be taken to ensure that any sensitive or proprietary information is kept out of the memo.*

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November 1, 2002

Date: _____

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| ELOS Originated by Wichita ACO: | Project Engineer Robert Adamson | Routing Symbol ACE-118W |